DTU Library

Special Issue on Wind Turbine Aerodynamics

Shen, Wen Zhong

Published in:
Applied Sciences

Link to article, DOI:
10.3390/app9091725

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

applied sciences

MDPI

Editorial

Special Issue on Wind Turbine Aerodynamics

Wen Zhong Shen

Department of Wind Energy, Technical University of Denmark, Nils Koppels Alle, Building 403, 2800 Lyngby, Denmark; wzsh@dtu.dk

Received: 20 April 2019; Accepted: 22 April 2019; Published: 26 April 2019

check for updates

1. Introduction

In order to reach the goal of 100% renewable energy in energy systems, wind energy, as a pioneer of renewable energy, is developing very quickly all over the world. To reduce the levelized cost of energy (LCOE), the size of a single wind turbine has been increased to 12 MW nowadays and it will increase further in the near future. Big wind turbines and their associated wind farms have many advantages but also challenges in aerodynamics, aero-elasticity and aeroacoustics. The typical effects are mainly related to the increase in Reynolds number and blade flexibility. This Special Issue collects some important works addressing the aerodynamic challenges appearing in such development. Aerodynamics of wind turbines is a classic concept and is the key for wind energy development as all other parts rely on the accuracy of its aerodynamic models. There are numerous books and articles dealing with wind turbine aerodynamic problems and models. As a good example, the wind energy handbook by Burton et al. [1] gives an overview of wind turbine aerodynamics and its related problems. There are also several special issues on wind turbine aerodynamics. This author edited a special issue on aerodynamics of offshore wind energy systems and wakes [2] in 2014, which collected state-of-the-art research articles on the development of offshore wind energy.

2. Current Status in Wind Turbine Aerodynamics

In the context introduced above, this special issue collects the latest research articles on various topics related to wind turbine aerodynamics, which includes atmospheric turbulent flow, wind turbine flow modeling, wind turbine design, wind turbine control, wind farm flow in complex terrain, wind turbine noise modeling, vertical axis wind turbine, and offshore wind energy. A summary of the collected papers is given below in the order mentioned above.

There are 4 papers dealing with atmospheric turbulent flow. Olivares-Espinosa et al. [3] addressed an assessment of turbulence modeling in the wake of an actuator disc with a decaying turbulence inflow and developed a method to replicate wake measurements obtained in a decaying homogeneous turbulence inflow produced by a wind tunnel. Ehrich et al. [4] compared the blade element momentum theory, actuator line method, and computational fluid dynamics in the case of a wind turbine under turbulence inflow by checking its sectional and integral forces in terms of mean, standard deviation, power spectral density and fatigue loads. As wind flow measurements are often carried out at low heights, Xu et al. [5] evaluated the power-law wind-speed extrapolation method for flows over different terrain types and a new wind-speed extrapolation method based on atmospheric stability classification methods was developed. Schaffarczyk and Jeromin [6] analyzed the measured high-frequency atmospheric turbulence and its impact on the boundary layer of wind turbine blades, and found that the stability state in the atmospheric boundary does not seem to depend on simple properties, but on higher statistical properties, such as shape factors.

There are 4 papers dealing with wind turbine simulation modeling. Xu et al. [7] developed a simplified free vortex wake model of wind turbines using vortex sheet for near wake and using ring wake for far wake. Zhu and Wang [8] studied dynamic stall phenomenon and rotational augmentation under pitch oscillation and oscillating freestream on wind turbine airfoil and blade using unsteady Reynolds averaged Navier–Stokes equations. Zhong et al. [9] analyzed the wind turbine stall prediction using Reynolds averaged Navier–Stokes simulations by turbulence coefficient calibration and found that the primary reason for the inaccuracy of rotor simulations is not rotational effects, but a turbulence-related modeling problem. Li et al. [10] conducted a study on the aerodynamic performance of a wind turbine airfoil DU 91-W2-250 under dynamic stall and found that an increased-reduced frequency leads to a lower aerodynamic efficiency during the upstroke process of pitching motions.

There are also 4 papers dealing with wind turbine design. Wu et al. [11] presented a framework to optimize the design of large-scale wind turbines by using different design objectives, such as levelized cost of energy, net present value, internal rate of return, and discounted payback time, and found that the blade obtained with economic optimization objectives has a much large relative thickness and smaller chord distributions than obtained with high aerodynamic performance design. Yang et al. [12] investigated the design of wind turbine in low wind speed areas by considering both blade length and hub height. Vorspel et al. [13] developed an optimization tool for rotor blades using bend-twist-coupling which allows the computation of gradients based on flow field at low cost. Cao et al. [14] developed a computational fluid dynamics/actuator disc-based wind turbine rotor optimization tool by considering wake effects and letting different designs for upstream and downstream turbines.

Concerning wind turbine control, Sanati et al. [15] investigated condition monitoring of wind turbine blades using both active and passive thermography in order to find the failure of wind turbine blades. Different image processing algorithms were used to increase the thermal contrasts of subsurface defects in thermal images obtained by active thermography, while a method of step phase and amplitude thermography was used for passive thermography.

There are 2 papers dealing with wind farm flow and layout optimization in complex terrain. Sessarego et al. [16] simulated wind turbine/farm flows in complex terrain using both Reynolds averaged Navier–Stokes with an actuator disc model and large eddy simulation with actuator line model and results were compared with detailed field measurements from two met-masts and SCADA (supervisory control and data acquisition) data. Feng et al. [17] developed an optimization framework for wind farm layout optimization in complex terrain, which employs a CFD (Computational Fluid Dynamics) wind resource assessment tool, an engineering wake model adapted in complex terrain and an advanced wind farm layout optimization algorithm, and it was found that the framework can provide a better layout than the original layout.

On wind turbine noise modeling, Sun et al. [18] developed an efficient numerical method for wind turbine noise modeling under multi-wake conditions. This model can predict simultaneously wind turbine flow and wake, wind turbine noise source and wind turbine noise propagation under different atmospheric conditions.

There are 2 papers dealing with the development of vertical axis wind turbines. Li et al. [19] designed a Lanzhou University of Technology (LUT) airfoil for straight-bladed vertical axis wind turbines with an objective of maximizing its aerodynamic performance. Zhao et al. [20] introduced a variable pitch approach for improving the performance of straight-bladed vertical axis wind turbine at rated tip-speed-ratio, and it was found that the new variable pitch approach can achieve an 18.9% growth of the peak power coefficient of the vertical axis wind turbine at the optimum tip-speed-ratio.

Offshore wind energy is a growing topic and this special issue collected 3 papers on this topic. Zhang and Kim [21] developed a fully coupled computational fluid dynamics method to analyze a semi-submersible floating offshore wind turbine under wind-wave excitation conditions and validated the model by inputting gross system parameters supported in the offshore code comparison, collaboration, continued with correlations project. Ke et al. [22] analyzed aerodynamic force and mechanical performance of a large wind turbine during typhoons using a weather research forecasting and computational fluid dynamics nesting method and found that typhoons increased the aerodynamic force and structure responses and decrease the overall buckling stability and ultimate bearing capacity of a 5 MW wind turbine. Guo et al. [23] studied the aerodynamic and motion performance of a 5 MW

H-type floating vertical axis wind turbine and it was found that the H-type floating VAWT (vertical axis wind turbine) has a better motion performance and the mean values of surge, heave and pitch of the H-type floating VAWT are smaller than those of the Φ-type floating VAWT.

3. Future Research Need

Although this special issue has been closed, more in-depth research in wind turbine aerodynamics is expected as the goal of wind energy research is to help the technological development of new environmental friendly and cost-effective wind energy systems.

Funding: This research received no external funding.

Acknowledgments: This special issue would not be possible without the contributions of various talented authors, hardworking and professional reviewers, and the dedicated editorial team of Applied Sciences. Congratulations to all the authors. I would like to take this opportunity to record my sincere gratefulness to all the reviewers. Finally, I place on record my gratitude to the editorial team of Applied Sciences, and special thanks to Nicole Lian, Assistant Managing Editor from MDPI Branch Office, Beijing.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Burton, T.; Jenkins, N.; Sharpe, D.; Bossanyi, E. *Wind Energy Handbook*, 2nd ed.; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2011.
2. Shen, W.Z.; Sørensen, J.N. Special Issue on Aerodynamics of Offshore Wind Energy Systems and Wakes. *Renew. Energy* **2014**, *70*, 1–2. [CrossRef]
3. Olivares-Espinosa, H.; Breton, S.P.; Nilsson, K.; Masson, C.; Dufresne, L.; Ivanell, S. Assessment of Turbulence Modelling in the Wake of an Actuator Disk with a Decaying Turbulence Inflow. *Appl. Sci.* **2018**, *8*, 1530. [CrossRef]
4. Ehrich, S.; Schwarz, C.M.; Rahimi, H.; Stoevesandt, B.; Peinke, J. Comparison of the Blade Element Momentum Theory with Computational Fluid Dynamics for Wind Turbine Simulations in Turbulent Inflow. *Appl. Sci.* **2018**, *8*, 2513. [CrossRef]
5. Xu, C.; Hao, C.; Li, L.; Han, X.; Xue, X.; Sun, M.; Shen, W. Evaluation of the Power-Law Wind-Speed Extrapolation Method with Atmospheric Stability Classification Methods for Flows over Different Terrain Types. *Appl. Sci.* **2018**, *8*, 1429. [CrossRef]
6. Schaffarczyk, A.P.; Jeromin, A. Measurements of High-Frequency Atmospheric Turbulence and Its Impact on the Boundary Layer of Wind Turbine Blades. *Appl. Sci.* **2018**, *8*, 1417. [CrossRef]
7. Xu, B.; Wang, T.; Yuan, Y.; Zhao, Z.; Liu, H. A Simplified Free Vortex Wake Model of Wind Turbines for Axial Steady Conditions. *Appl. Sci.* **2018**, *8*, 866. [CrossRef]
8. Zhu, C.; Wang, T. Comparative Study of Dynamic Stall under Pitch Oscillation and Oscillating Freestream on Wind Turbine Airfoil and Blade. *Appl. Sci.* **2018**, *8*, 1242. [CrossRef]
9. Zhong, W.; Tang, H.; Wang, T.; Zhu, C. Accurate RANS Simulation of Wind Turbine Stall by Turbulence Coefficient Calibration. *Appl. Sci.* **2018**, *8*, 1444. [CrossRef]
10. Li, S.; Zhang, L.; Yang, K.; Xu, J.; Li, X. Aerodynamic Performance of Wind Turbine Airfoil DU 91-W2-250 under Dynamic Stall. *Appl. Sci.* **2018**, *8*, 1111. [CrossRef]
11. Wu, J.; Wang, T.; Wang, L.; Zhao, N. Impact of Economic Indicators on the Integrated Design of Wind Turbine Systems. *Appl. Sci.* **2018**, *8*, 1668. [CrossRef]
12. Yang, H.; Chen, J.; Pang, X. Wind Turbine Optimization for Minimum Cost of Energy in Low Wind Speed Areas Considering Blade Length and Hub Height. *Appl. Sci.* **2018**, *8*, 1202. [CrossRef]
13. Vorspel, L.; Stoevesandt, B.; Peinke, J. Optimize Rotating Wind Energy Rotor Blades Using the Adjoint Approach. *Appl. Sci.* **2018**, *8*, 1112. [CrossRef]
14. Cao, J.; Zhu, W.; Shen, W.; Sørensen, J.N.; Wang, T. Development of a CFD-Based Wind Turbine Rotor Optimization Tool in Considering Wake Effects. *Appl. Sci.* **2018**, *8*, 1056. [CrossRef]
15. Sanati, H.; Wood, D.; Sun, Q. Condition Monitoring of Wind Turbine Blades Using Active and Passive Thermography. *Appl. Sci.* **2018**, *8*, 2004. [CrossRef]

16. Sessarego, M.; Shen, W.Z.; Van der Laan, M.P.; Hansen, K.S.; Zhu, W.J. CFD Simulations of Flows in a Wind Farm in Complex Terrain and Comparisons to Measurements. *Appl. Sci.* **2018**, *8*, 788. [CrossRef]
17. Feng, J.; Shen, W.Z.; Li, Y. An Optimization Framework for Wind Farm Design in Complex Terrain. *Appl. Sci.* **2018**, *8*, 2053. [CrossRef]
18. Sun, Z.; Zhu, W.J.; Shen, W.Z.; Barlas, E.; Sørensen, J.N.; Cao, J.; Yang, H. Development of an Efficient Numerical Method for Wind Turbine Flow, Sound Generation, and Propagation under Multi-Wake Conditions. *Appl. Sci.* **2019**, *9*, 100. [CrossRef]
19. Li, S.; Li, Y.; Yang, C.; Zhang, X.; Wang, Q.; Li, D.; Zhong, W.; Wang, T. Design and Testing of a LUT Airfoil for Straight-Bladed Vertical Axis Wind Turbines. *Appl. Sci.* **2018**, *8*, 2266. [CrossRef]
20. Zhao, Z.; Wang, R.; Shen, W.; Wang, T.; Xu, B.; Zheng, Y.; Qian, S. Variable Pitch Approach for Performance Improving of Straight-Bladed VAWT at Rated Tip Speed Ratio. *Appl. Sci.* **2018**, *8*, 957. [CrossRef]
21. Zhang, Y.; Kim, B. A Fully Coupled Computational Fluid Dynamics Method for Analysis of Semi-Submersible Floating Offshore Wind Turbines Under Wind-Wave Excitation Conditions Based on OC5 Data. *Appl. Sci.* **2018**, *8*, 2314. [CrossRef]
22. Ke, S.; Yu, W.; Cao, J.; Wang, T. Aerodynamic Force and Comprehensive Mechanical Performance of a Large Wind Turbine during a Typhoon Based on WRF/CFD Nesting. *Appl. Sci.* **2018**, *8*, 1982. [CrossRef]
23. Guo, Y.; Liu, L.; Gao, X.; Xu, X. Aerodynamics and Motion Performance of the H-Type Floating Vertical Axis Wind Turbine. *Appl. Sci.* **2018**, *8*, 262. [CrossRef]